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Utilizing metal-insulator-semiconductor (MIS) capacitors to extract the temperature dependence of doping density and mobility for the semiconductor poly(3-hexylthiophene), P3HT

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Abstract – We describe the results of an investigation into the frequency- and voltage-dependence of capacitance and conductance of organic metal-insulator-semiconductor (MIS) capacitors over the temperature range 210-380K. From these data we extract the temperature-dependence of the acceptor doping density and carrier mobility in the semiconductor. The doping density was found to be weakly dependent on temperature while the mobility showed the Arrehnius behavior with activation energy of 0.15 eV.

Measuring the frequency and voltage dependences of capacitance and conductance [1] of metal-insulator-semiconductor (MIS) capacitors is a valuable methodology for characterizing (*a*) the semiconductor, (*b*) the semiconductor-dielectric interface and (*c*) the dielectric itself. We present here the results of such a study into an MIS capacitor fabricated from the organic *p*-type semiconductor poly(3-hexylthiophene), P3HT, as the active layer and a photo resist as the gate dielectric. The main objective was to determine the temperature-dependences of the acceptor doping density and carrier mobility in the P3HT.

The MIS capacitors were fabricated on indium tin oxide ITO coated glass by spin-coating a photo resist layer ~350 nm thick which was cured both thermally and by UV irradiation. The insulator surface was rendered hydrophobic by exposure to hexamethyldisilizane (HMDS). The P3HT was spin-coated onto the insulator from a 1%wt chloroform solution to a final thickness of 100 nm. Circular gold contacts (2.0 ± 0.2 mm in diameter) were formed on the semiconductor surface by vacuum evaporation through a mask.

The *ac* measurements were made using an impedance analyzer (Solartron 1260 coupled to the dielectric interface 1296) over the frequency range of 10 Hz–1 MHz and for applied voltages in the range of ±15 V. The ac signal amplitude was 100 mV. Temperature was varied over the range 210-380 K and measurements were taken at a pressure less than 10^{-5} torr after a thermal treatment at 100^{o}C to remove adventitious dopants such as oxygen from the P3HT semiconductor.

Following the standard Mott-Schottky analysis [2] the acceptor doping density N_A in the *p*-type semiconductor was extracted from the linear part of capacitance versus voltage plots [3]. From the *ac* response of a two-layer dielectric, the relaxation frequency arising from the so-called Maxwell-Wagner effect was identified and used to extract the electrical conductivity, σ, of the P3HT film at each temperature. Finally, the mobility, μ, was calculated from the relation $\sigma = q\mu N_A$, where q is the electronic charge.

The doping density was found to be weakly dependent of temperature increasing through the range (0.6 to 1) x 10^{16} cm^{-3}. The carrier mobility increased from (0.01 to 1) x10^{-3} cm^2/Vs as the temperature increased from 210 to 380 K, following an Arrhenius temperature dependence which yielded an activation energy of 0.15 eV. This agrees with a model of thermally activated transport as proposed by Holstein [4].

References

[1] E. H. Nicollian and A. Goetzberger, Bell Syst. Tech. J. **46** (1967) 1055.
[2] S. M. Sze, Physics of Semiconductor Devices, 2nd ed., Wiley Interscience, New York, 1981.
[3] I. Torres and D. M. Taylor, J. Appl. Phys. 98 (2005) 073710.
[4] T. Holstein, Ann. Phys. 8 (1959) 343.